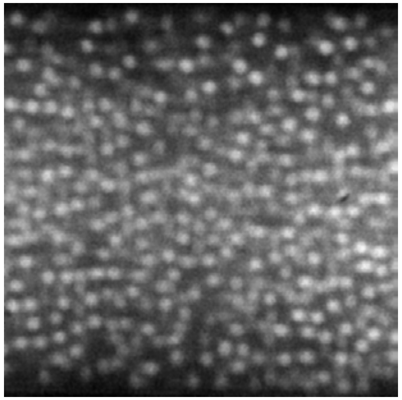
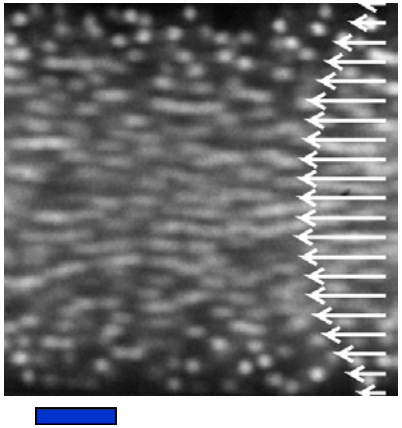
CAREER: Static Properties and Dynamical Behavior of Jammed Systems

Eric R. Weeks, Emory University, DMR-0239109

Flows of liquids containing particles are important for applications including ink-jet printers and "Lab on a Chip" devices that manipulate tiny quantities of materials. We study how such flows behave in tiny tubes, and in particular we are looking for situations in which the particles jam and clog the tube. We see a particle migration effect, causing particles to move toward the center of the tube, thus helping prevent clogging. We plan to next study what happens when the tube suddenly constricts, such as at an ink-jet nozzle.



A single snapshot of a relatively dilute concentration of particles. We use a fast confocal microscope to take this picture; the 2 micron diameter particles are moving to the left.



10 μm

A sequence of snapshots is superimposed, revealing that the particles are in motion. The arrows show the particles' velocities, slower near the walls and fast in the middle. The maximum velocity is 120 microns / s.

The flow of liquids containing particles is of wide-spread interest, with applications in industry. Furthermore, studying these flows can provide fundamental physical understanding of these complex fluids. Our work is looking for situations in which particle-laden liquids can jam in microscopic tubes, which for example can be similar to ink-jet printer nozzles. We study a liquid containing small plastic particles. This is simple model system that is easier to understand experimentally and theoretically. Our group uses a fast confocal microscope, an optical microscope which uses a laser in order to see deep inside the tubes and take clear images of the flowing material. Particles moving in slightly different regions of the tube move at slightly different speeds. As two particles move past each other with different speeds, they slightly disturb each other. These somewhat random disturbances cause the particles to move around. However, when the particles are closer to the center, most particles have the same speeds, and thus disturb each other less. This is seen in these pictures, that more particles are in the center of the tube. Thus the particles are less likely to clog the tube. We plan to next study what happens when the particles flow through a constriction. In such a case, having more particles in the center of the tube may enhance clogging. Some previous work on these questions has been done by groups studying large particles such as sand; we are interested in how jamming happens in cases where the particles experience less friction with each other, as they are so much smaller.

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Education:

Two undergraduates (Doug Anderson and Martin Frank) and one postdoctoral fellow (Denis Semwogerere) contributed to this work. Doug Anderson is starting graduate school at the University of Georgia in Fall 2004, and Martin Frank will be a senior at Emory this fall.

Two other undergraduates and one graduate student will start work on related projects starting Fall 2004.

Societal Impact:

Many groups work on “Lab on a Chip” projects: designing devices to analyze and process small amounts of materials, such as biological samples or chemical samples. Most of this work deals with manipulating small amounts of simple fluids such as water. Our experiments learn crucial information about the small-scale flows of complex fluids. In particular jamming and clogging of complex fluids needs to be understood and prevented, in order for “Lab on a Chip” devices to have widespread utility.